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Physiological rationale and clinical use of lateral positioning in ARDS

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Acute respiratory distress syndrome (ARDS) is a life-threatening form of respiratory failure most commonly triggered by pneumonia, aspiration, sepsis, or trauma. Despite advances in supportive care, morbidity and mortality remain substantial. Standard-of-care treatment includes lung-protective mechanical ventilation, and prone positioning in severe cases. Prone positioning improves oxygenation and survival when implemented early in patients with a PaO_2/FiO_2 ratio < 150 mmHg and maintained for prolonged durations (> 16 h) [1], by promoting more homogeneous ventilation-perfusion matching and reducing ventilator-induced lung injury (VILI).

Body positioning is a fundamental component of ARDS management. Transitions from the supine position to semi-recumbent, prone, or lateral positions are routine in daily ICU care to optimize oxygenation, facilitate secretion clearance, and prevent pressure injuries [1–4]. With the growing appreciation of ARDS as a heterogenous lung injury affecting dependent and non-dependent lung regions differently, lateral positioning has resurfaced as a potential strategy to modulate regional lung mechanics and gas exchange.

This review synthesizes the physiological principles, clinical evidence, practical applications, and limitations of lateral positioning in ARDS.

1. Physiological rationale for lateral positioning

1.1. Heterogeneous lung injury, gravity, and stress–strain distribution

ARDS is an intrinsically heterogeneous disease. Dependent lung regions are particularly susceptible to collapse and cyclic recruitment, generating localized zones of elevated stress and strain, whereas non-dependent regions may become overdistended under conventional ventilation. In the supine position, gravity produces a vertical gradient in pleural pressure [5]. As superimposed pressure increases from ventral to dorsal, the transpulmonary pressure (P_L = airway pressure (Paw) – pleural pressure (Ppl)) is lowest in the dependent dorsal lung regions—favoring derecruitment— and highest in ventral regions, promoting overinflation [6] (Fig. 1). Concurrently, pulmonary perfusion preferentially favours dependent lung regions, resulting in ventilation–perfusion (V/Q) mismatch and contributing to hypoxemia.

Importantly, these effects are not uniform across patients and depend on lung mechanical properties and recruitability. In highly recruitable lungs, increases in P_L preferentially reopen collapsed tissue and improve lung homogeneity, whereas in poorly recruitable lungs, increased inflation pressure may disproportionately elevate vascular resistances, potentially worsening right ventricular coupling and hemodynamics [7].

1.2. How lateral positioning modulates mechanics

Transitioning to the lateral decubitus position reorients gravitational forces along the right–left axis. The resulting vertical pleural pressure gradient is greater than that observed in the supine position, increasing mechanical heterogeneity between dependent (lower) and non-dependent (upper) lungs. Non-dependent lung regions experience increased P_L, favoring recruitment of previously collapsed areas, while

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dependent regions are exposed to lower P_L and, therefore face a higher risk of collapse unless supported by adequate PEEP [8].

In a cohort of early mechanically ventilated patients managed with individualized PEEP based on the recruitment-to-inflation (R/I) ratio, sequential lateral positioning improved respiratory system compliance, reduced driving pressure, and enhanced oxygenation while promoting dorsal redistribution of end-expiratory lung volume. These physiological effects were most pronounced in patients with higher lung recruitability (R/I ratio $>$ 0.5) [9]. However, the mechanical effects of lateral positioning appear to be angle-dependent and asymmetric. Stepwise lateral positioning induces progressive changes in respiratory mechanics, with left lateral positioning at higher inclinations producing greater reductions in compliance and increases in driving pressure than right lateral positioning [10].

1.3. Role of PEEP and position-dependent requirements

In experimental models of acute lung injury with high recruitability, lateral positioning significantly alters the regional transpulmonary pressure distribution by reorienting gravitational pleural pressure gradients. Transitioning from the supine to the lateral position increased pleural pressure gradients from approximately 3 cmH_2O in the anteroposterior axis to about 6 cmH_2O across the right–left axis. This results in higher P_L in the non-dependent lung and lower pressures in the dependent lung, promoting recruitment of upper lung regions while increasing the risk of derecruitment in dependent regions unless adequately counterbalanced by PEEP [11].

Electrical impedance tomography (EIT)-guided PEEP titration during sequential lateral positioning has demonstrated preservation of dependent lung aeration and recruitment of nondependent regions, improving compliance and oxygenation without inducing overdistension. These findings highlight the limitations of using fixed PEEP during lateral positioning [8]. In COVID-19–related ARDS, lateral positioning reduced both collapse and overdistension in diseased lungs at PEEP levels similar to those used in the supine position, suggesting posture-driven recruitment rather than pressure escalation as the primary mechanism [8]. The wide interindividual variability in optimal PEEP (4–20 cmH_2O) reinforces the need for personalized adjustments during lateral positioning [8].

1.4. Perfusion and V/Q matching

Pulmonary perfusion remains predominantly gravity-dependent, although disease-related heterogeneity, vascular remodelling, hypoxic vasoconstriction, and COVID-19–related microvascular alterations introduce substantial variability. By improving aeration in previously collapsed regions and reducing hyperinflation in non-dependent lungs, lateral positioning may improve $\dot{V}/\dot{Q}$ matching and reduce intrapulmonary shunt [11]. In patients with pronounced unilateral involvement, positioning the healthier lung in the dependent position may maximize perfusion to better-ventilated regions. Conversely, the "bad lung up" strategy may improve oxygenation by enhancing $\dot{V}/\dot{Q}$ matching and reducing shunt; however, it may also promote collapse of the dependent, healthier lung, raising important concerns regarding physiological trade-offs and clinical safety.

2. Clinical experience with lateral positioning in ARDS

Despite a strong physiological rationale, clinical experience with lateral positioning in ARDS remains limited. Most available data derive from small physiological studies, crossover designs with short intervention durations, and heterogeneous patient populations [8,9].

Historically, lateral positioning was applied in patients with unilateral pneumonia or atelectasis to redirect ventilation and perfusion toward the healthier lung and improve arterial oxygenation [12]. More recent physiological studies have reported improvements in oxygenation when the better-aerated lung was placed dependently, although responses were variable and strongly influenced by disease distribution and baseline lung mechanics [9,11]. During the COVID-19 pandemic, sequential lateral positioning was shown to redistribute ventilation toward dependent regions (as assessed by EIT), improve regional compliance, and enhance oxygenation—particularly after returning to the supine position—and especially in patients with high lung recruitability [9].

However, clinical results remain inconsistent. Some cohorts reported meaningful improvements in PaO_2/FiO_2 and respiratory mechanics, particularly in asymmetric ARDS with marked right–left heterogeneity, whereas others observed minimal physiological changes [8,9]. These heterogeneous responses likely reflect differences in lung recruitability, extent of consolidation, adequacy of PEEP titration, right ventricular

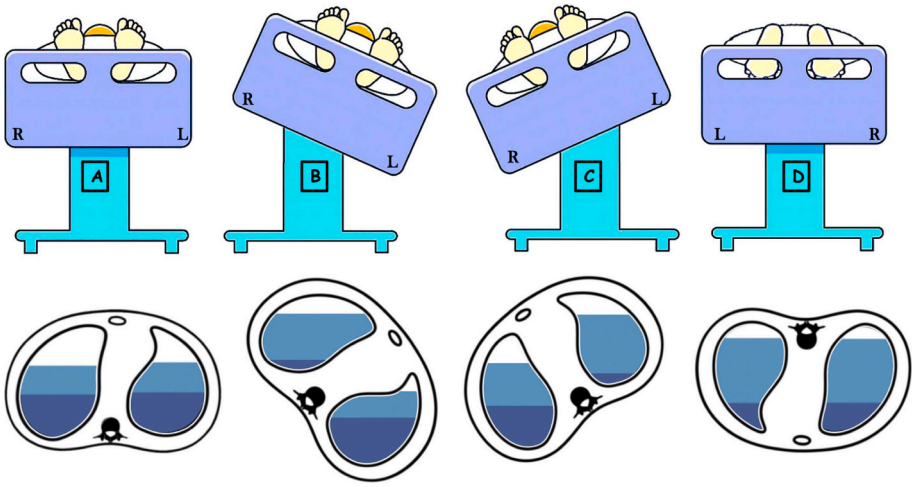

Fig. 1. Schematic representation of changes in lung aeration according to patient position.
The second row illustrates expected regional ventilation patterns in the supine (A), left lateral (B), right lateral (C), and prone (D) positions. White areas indicate potential overdistension, light blue areas indicate predominantly normal ventilation, and dark blue areas indicate poorly or non-aerated lung regions. In ARDS, dependent collapsed regions in the supine position may reopen in the prone position, with a concomitant reduction in overdistension. In lateral positions (B and C), ventilation is redistributed between dependent and non-dependent lungs, improving aeration of previously collapsed regions in the nondependent lung, albeit with an increased risk of overdistension. Slightly reduced aeration of the dependent lung may occur, justifying adjustment of PEEP levels. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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function, and positional angle thresholds. Importantly, unlike prone positioning, no randomized trials have demonstrated morbidity or mortality benefits with lateral positioning, highlighting the need for further translational and clinical investigation.

3. Practical considerations for implementation

Ideal candidates for lateral positioning are patients with ARDS presenting with asymmetric radiographic involvement, those who demonstrate oxygenation improvement during short lateralization trials performed for nursing care, and/or those with contraindications to prone positioning.

The angle used is usually 30°–45° from the supine position (seeking the optimal balance between alveolar recruitment and overdistension on the one hand, and improved oxygenation and haemodynamic stability on the other), although full lateral decubitus position may be used. Therapeutic sessions may last from 30 min to more than 6 h—shorter durations when lung lesions are homogeneously distributed and longer durations in the presence of significant unilateral involvement. Caution is warranted in patients with severe right ventricular dysfunction or hemodynamic instability, as posture-induced changes in transpulmonary pressure and pulmonary vascular resistances may adversely affect cardiovascular performance [3].

Short lateralization trials with close monitoring of gas exchange, respiratory mechanics, EIT if available, and hemodynamics may help identify responders before prolonged application [10], guide side selection, and detect dependent derecruitment or non-dependent overdistension during lateral positioning in order to set the best PEEP level for each side (best trade-off to limit derecruitment and to lessen overdistension).

4. Adverse effects

As with prone positioning, lateral positioning requires experienced staff and standardized protocols to minimize complications. Reported adverse events include accidental extubation, catheter dislodgement, hypotension, hypoxemia, and hemodynamic compromise—particularly at higher inclination angles (>60°) [13].

5. Advantages and limitations

Lateral positioning is a simple, low-cost intervention requiring minimal equipment. It is particularly useful in asymmetric ARDS and may serve as an alternative when prone positioning is not feasible. Potential benefits include improved ventilation–perfusion matching, reduced regional mechanical stress, enhanced secretion clearance, and applicability in both ventilated and non-ventilated patients. However, the evidence based remains limited, and no morbidity or mortality benefits have been demonstrated. Accordingly, lateral positioning should be considered an individualized, physiology-guided adjunct rather than a substitute for established therapies, such as lung-protective ventilation and prone positioning. The use of lateral positioning in awake non-intubated with unilateral or asymmetrical hypoxemic respiratory failure needs also further assessment.

6. Conclusion

Lateral positioning in ARDS has a compelling physiological rationale grounded in gravity-mediated modulation of regional lung mechanics, $\dot{V}/Q$ matching, and recruitment. However, its effects on clinically meaningful outcomes, including duration of mechanical ventilation and mortality, have not been formally evaluated. Additional physiological studies and prospective observational studies addressing the specific risks and benefits of lateral positioning are needed. Protocol optimization—including positioning angle, duration, and integration with proning cycles—also warrants investigation. Until such data are available, prone positioning should remain the preferred strategy, even in cases of unilateral or asymmetrical ARDS, and lateral positioning should be regarded as a physiology-based adjunct, particularly in asymmetric ARDS and/or when prone positioning is not feasible.

Authors approval

All authors have approved the submitted version of the manuscript.

Use of AI

No use of generative AI for the preparation of the manuscript.

CRediT authorship contribution statement

Marie-Thérèse Al-Andary: Writing – original draft. **Martin Benites:** Writing – review & editing. **Jaime Retamal:** Writing – review & editing. **Laurent Papazian:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Laurent Papazian reports a relationship with LINET that includes: funding grants. Laurent Papazian reports a relationship with Air Liquide Health France that includes: consulting or advisory. Laurent Papazian reports a relationship with Faron Pharmaceuticals Oy that includes: consulting or advisory. Laurent Papazian reports a relationship with Merck Sharp & Dohme UK Ltd. that includes: consulting or advisory. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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